Clean Heating Technologies

Green Transformation of District Heating and Cooling

Asia Clean Energy forum June 2023

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“Technologies” = technical solutions =
Applications, Resources, and Technologies (ART)

Applications: space heating and cooling, power generation
Resources: geothermal and other renewable energy
Technologies: pumps, heat exchangers, heat pumps, PV, etc.

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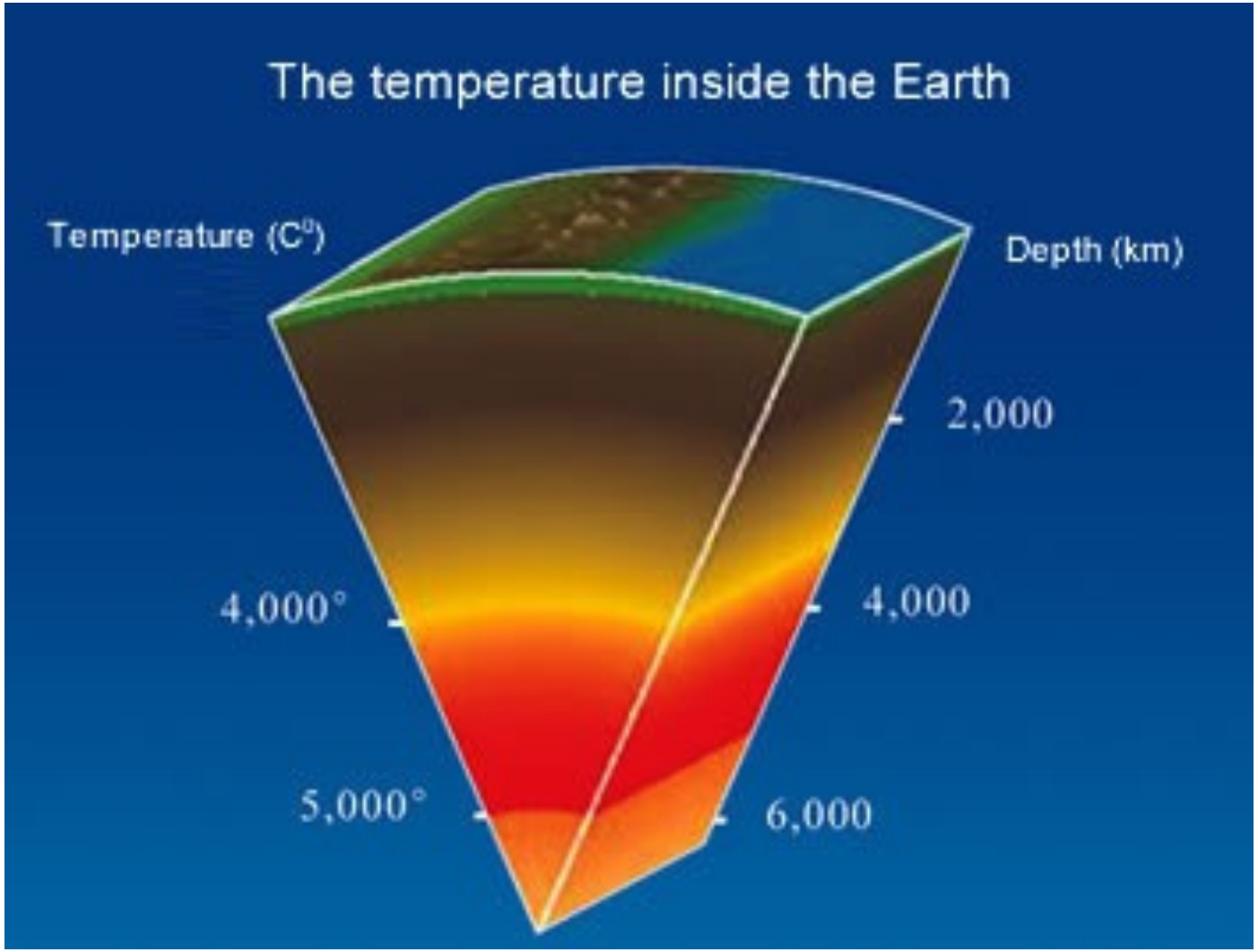
GEOTHERMAL ENERGY IS EVERWHERE!



In order of increasing abundance:

- > 200 ℃ for steam turbine power plants
- > 110 ℃ for binary / organic Rankine cycle (ORC*) heat-to-power plants
- > 50 ℃ for direct use in district heating, agriculture, aquaculture, etc.
- 12 - 15 ℃ for shallow ground-source heat pumps

* Binary / ORC family of technologies has huge potential for other applications including ocean thermal energy conversion (OTEC)

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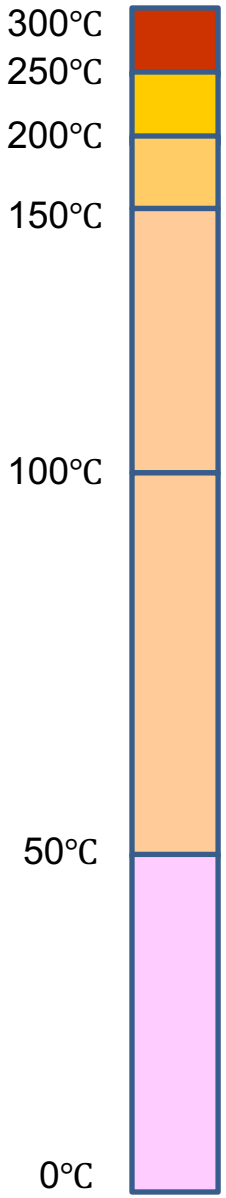
"Geothermal +$+$" => *cascading uses => multiple revenue streams*



(1) monetize ***heat from oil & gas fields***… > 10,000 MW potential in Ustyurt-Buzashin Basin
+ (2) recovery of minerals & high-value metals from oil & gas brines (?)… + (3) desalinated water (?)…
+ (4) export this experience and knowledge for profit in other countries (MASDAR model)

ORC 110+ ℃:
heat-to-power in oil & gas fields, industrial boilers, etc.

50+ ℃:
district heating

40+ ℃:
Climate-proof greenhouse agriculture,
agro-processing, & aquaculture, etc.

12 – 15 ℃: shallow ground-source heat pumps
for space heating & cooling

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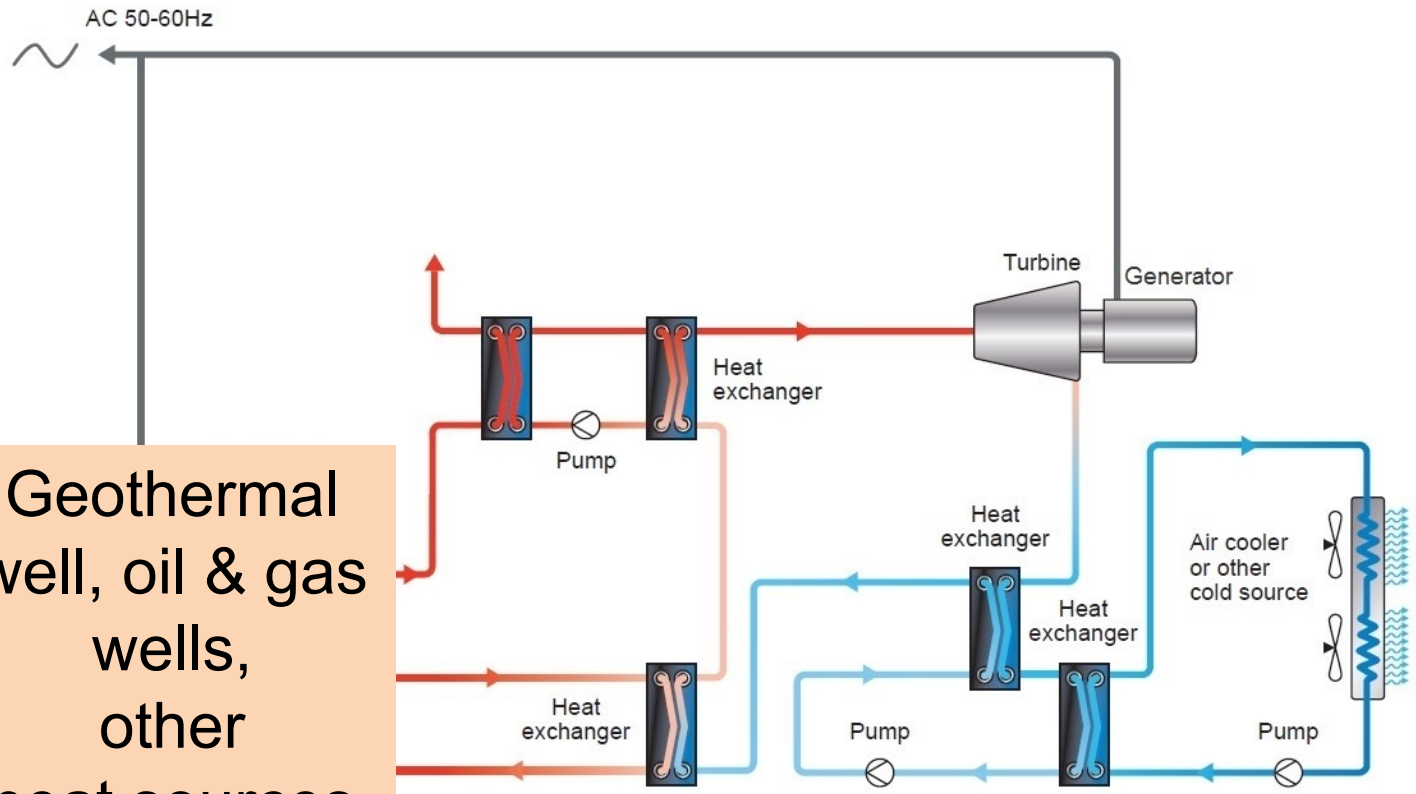
Organic Rankine Cycle (ORC) Heat to Power
Geothermal wells and other heat sources are the fuel!

- ORC closed-loop heat transfer - working fluid with boiling point lower than the boiling point of water
- ORC modular units, typically 100 kW - 150 kW per unit
- ***Undiscounted LCOE ~ $0.05 / kWh***



Geothermal well, oil & gas wells, other heat sources

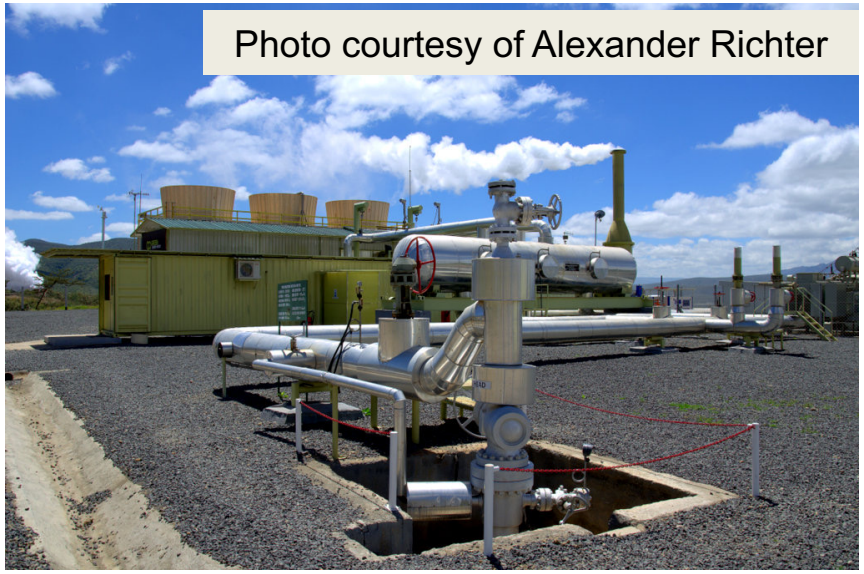
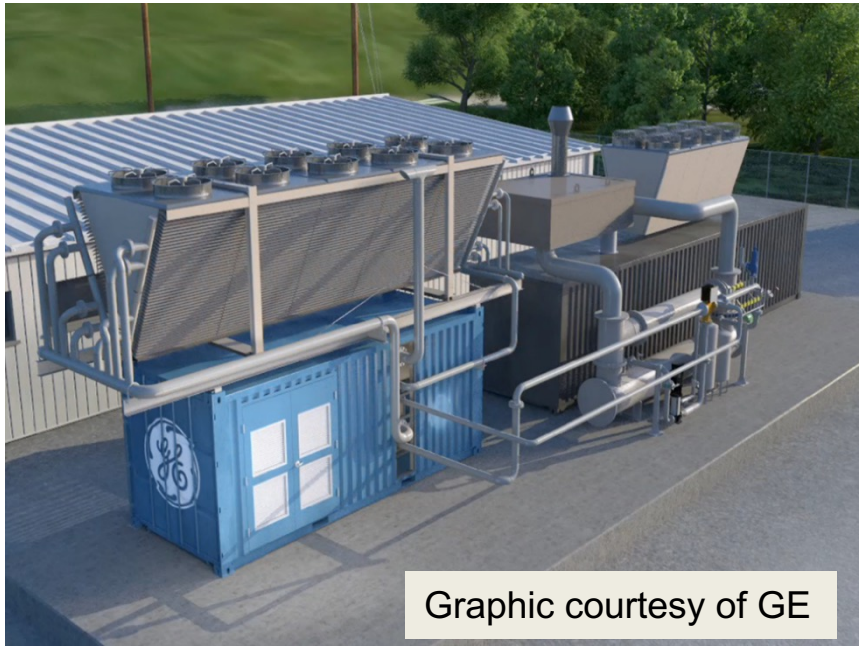


Photo courtesy of Alexander Richter



Graphic courtesy of GE

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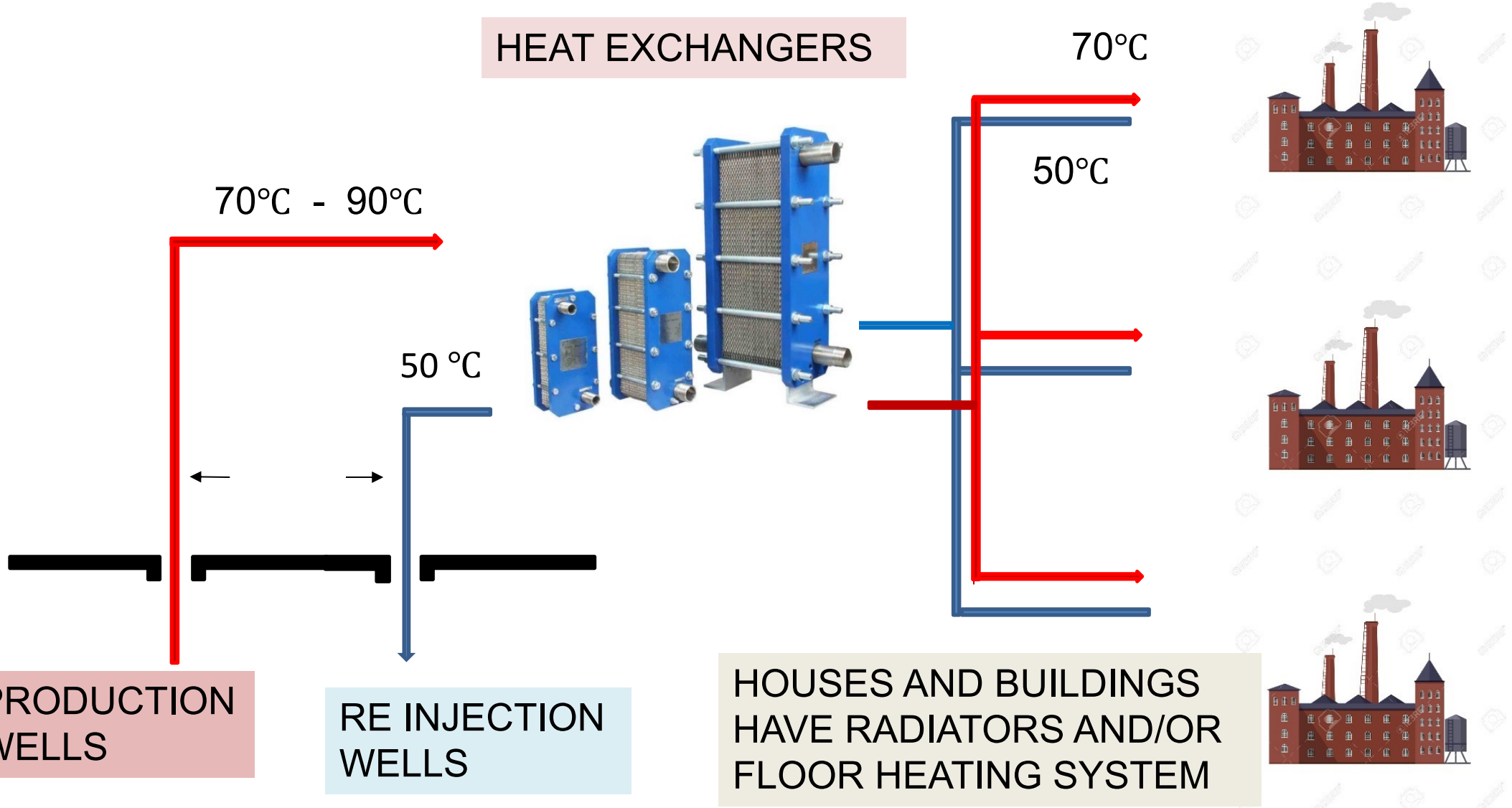
The geothermal wells are the fuel!
The technologies are pumps, heat exchangers, and heat pumps



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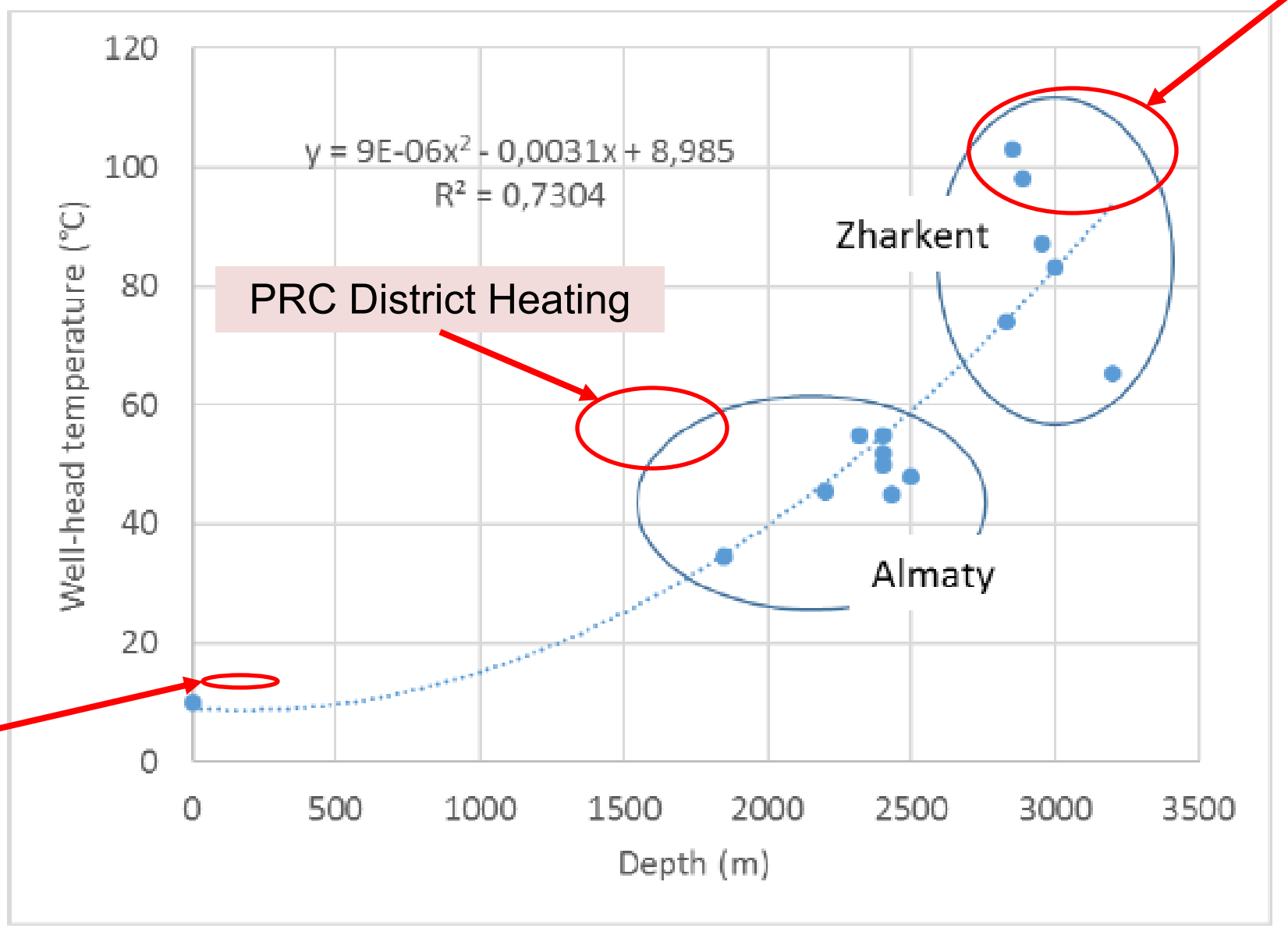
Kazakhstan Geothermal Resource Targets

90 - 110 C for ORC generation



PRC District Heating

Ground source heat pumps

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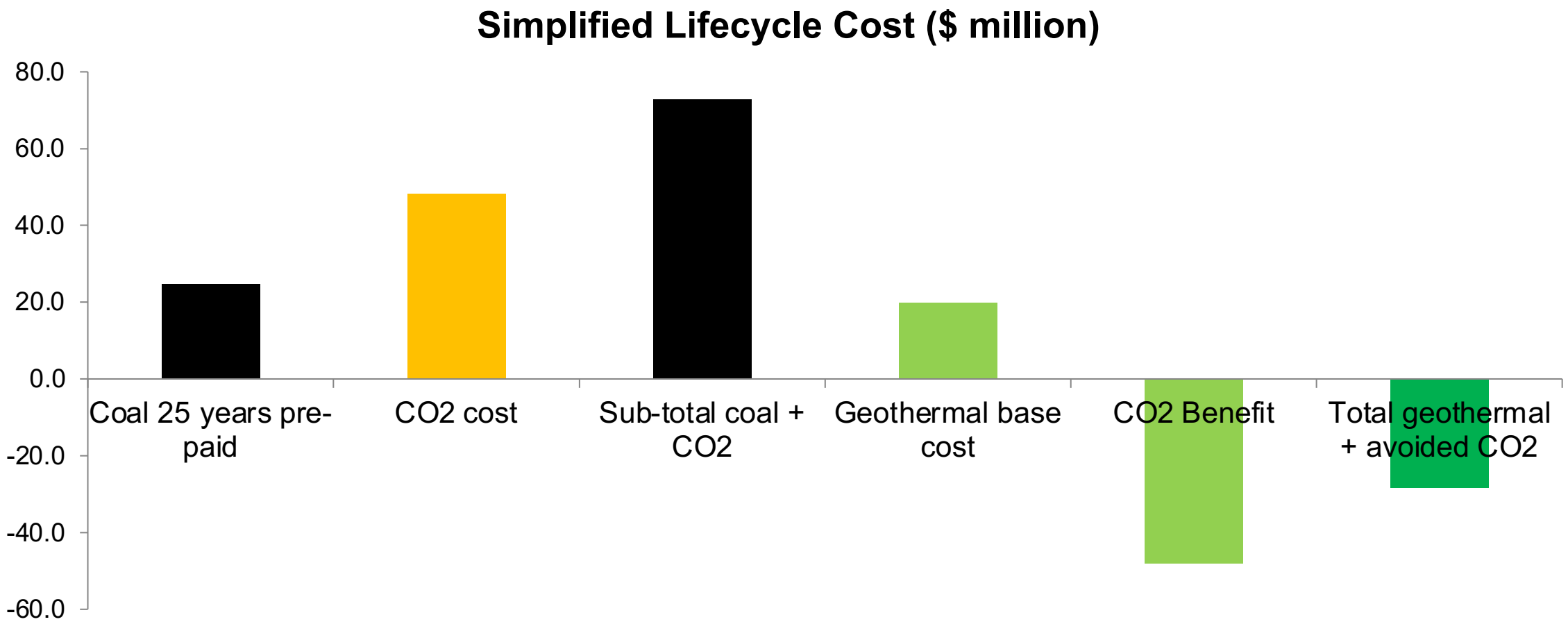
PRC Shandong Dezhou ("Texas") City Geothermal District Heating (ADB 2017)

Total cost of geothermal district heating project is less than the cost of fuel for a coal-fired project

When avoided cost of CO2 is included, total cost of geothermal is negative, i.e., geothermal pays for itself $$$

Dezhou project Financial IRR = 11.2% Economic IRR = 9.2%



Cost of coal assumed at $75/ton, 13,119 tons/year, pre-paid for 25 years of supply. Cost of carbon = $50 / ton CO2.

Project covers 800,000 m2 heating area in new urban development. Geothermal cost from Shandong Luhai Petroleum Technology Co. Ltd.

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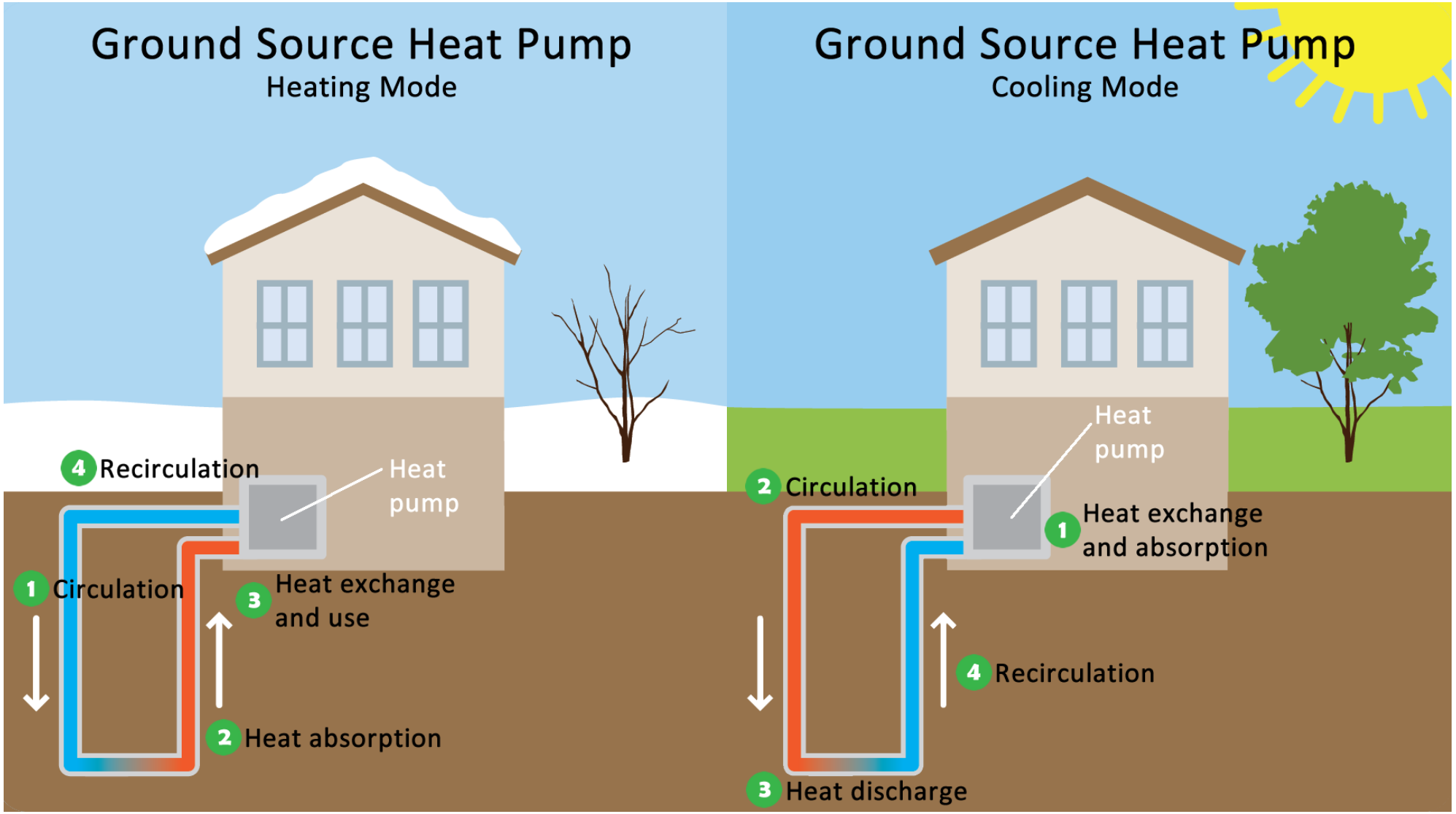
GEOTHERMAL ENERGY IS EVERYWHERE !!!

Subsurface temperature 12 ℃ - 15 ℃ is waiting to be harvested with closed-loop ground source heat pumps. Financial viability is primarily a function of depth to the thermal resource.



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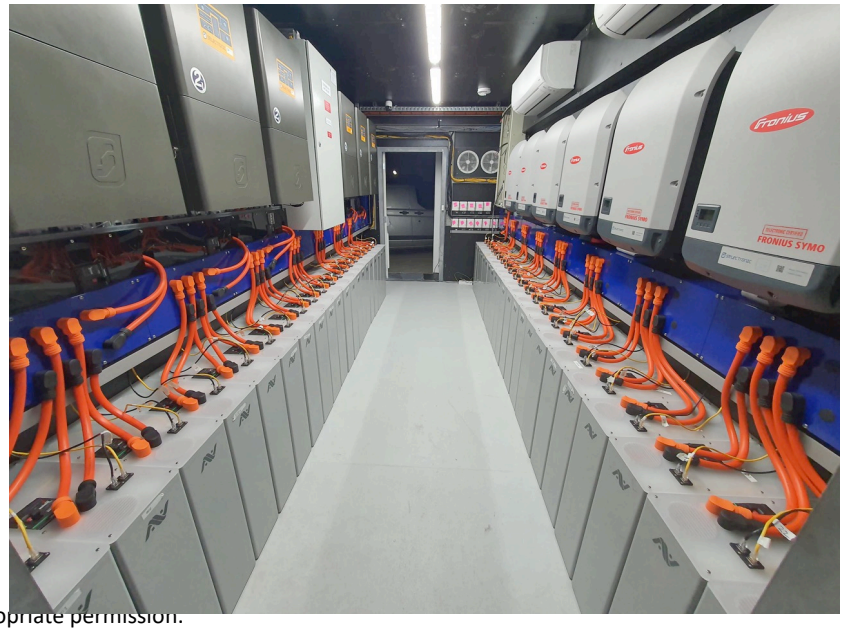
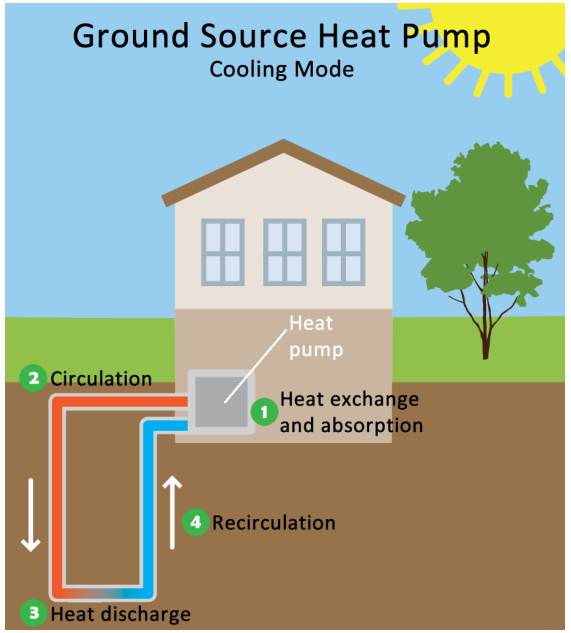
Add solar PV, solar thermal, wind, and energy storage for 100% zero-emissions operation





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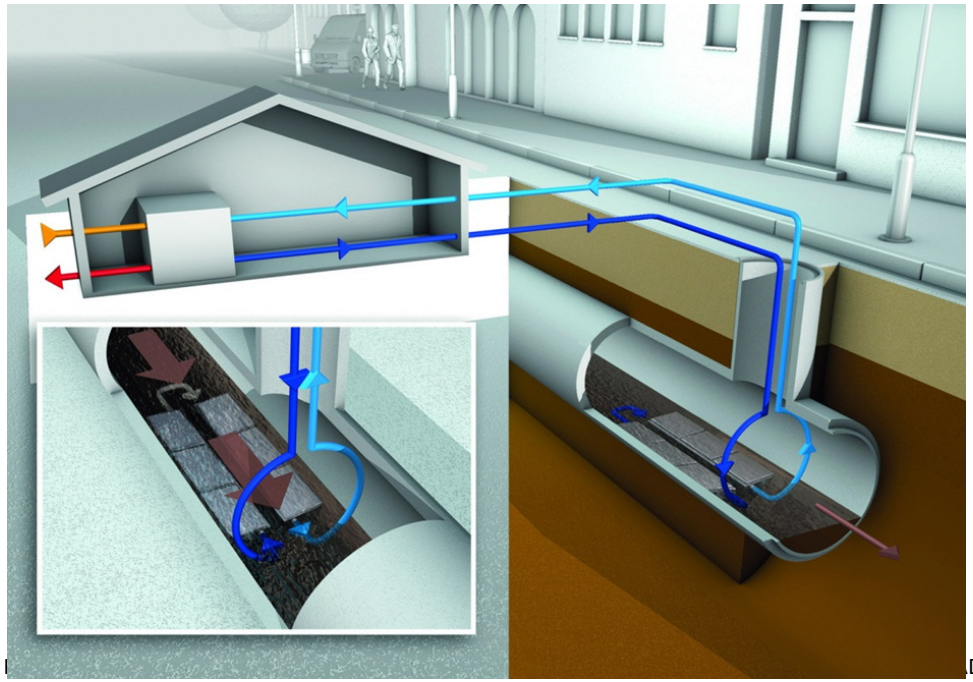
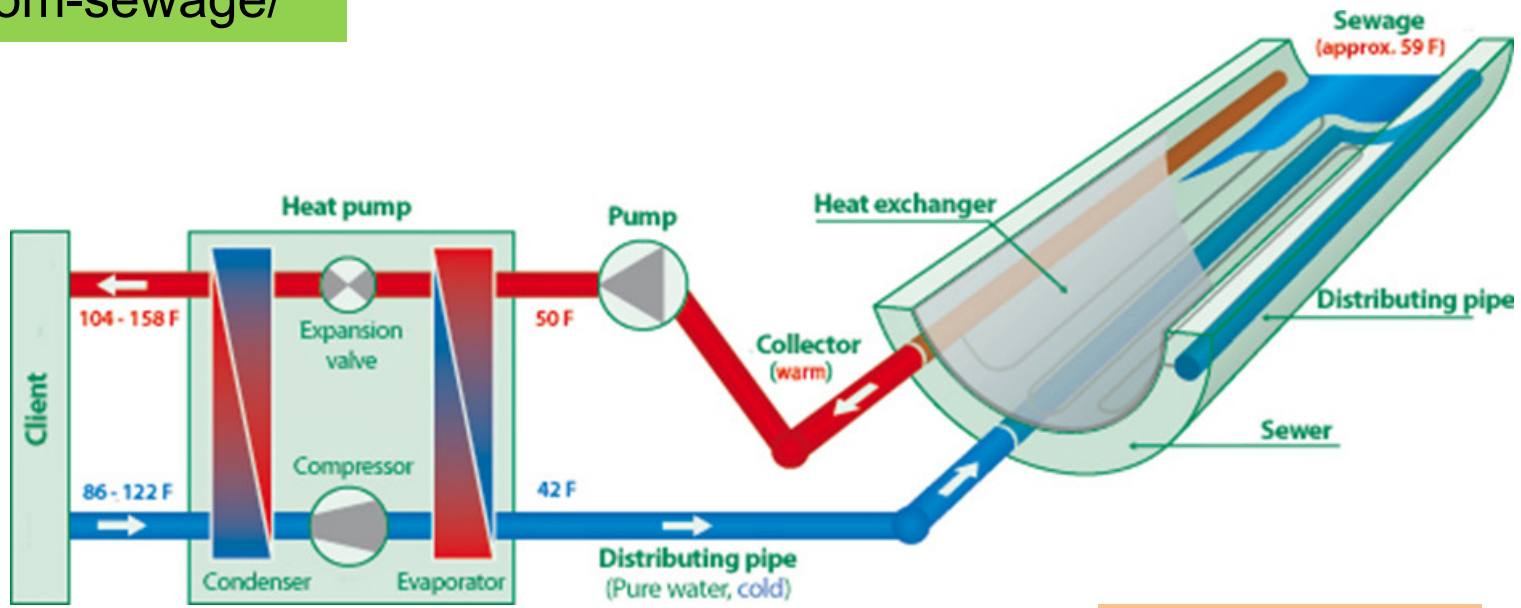
Heat recovery from sewage systems – heat exchangers and pumps

https://celsiuscity.eu/clean-energy-from-sewage/

Retrofit



New build



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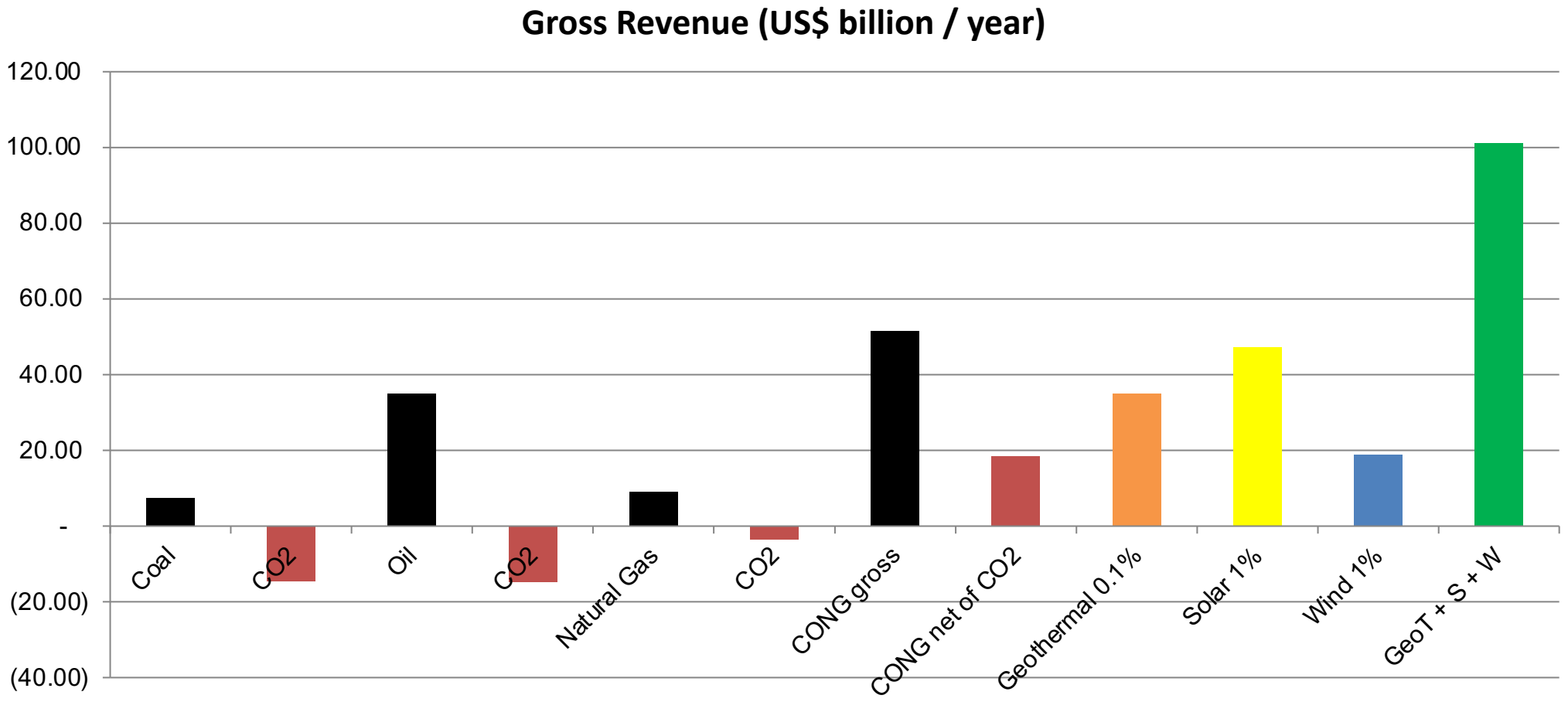
Kazakhstan's Energy Wealth: Revenue Scenario Including Cost of Carbon



Geothermal 0.1% of estimated resource @ 80% capacity utilization factor @ $50/MW-h
Solar 1% of land area @ 25 MW / km2 @ 15% capacity utilization factor @ $50/MW-h
Wind 1% of land area @ 5 MW / km2 @ 33% capacity utilization factor @ $50/MW-h

Coal at $75 / ton
Oil @ $50 / barrel
Natural gas @ $300 / 1000 m3
CO2 @ $50 / ton

* Source for oil and gas reserves and production: https://www.trade.gov/energy-resource-guide-oil-and-gas-kazakhstan
** Source for coal: IEA

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We cannot predict the future,
but we are constantly building it

Thank you!

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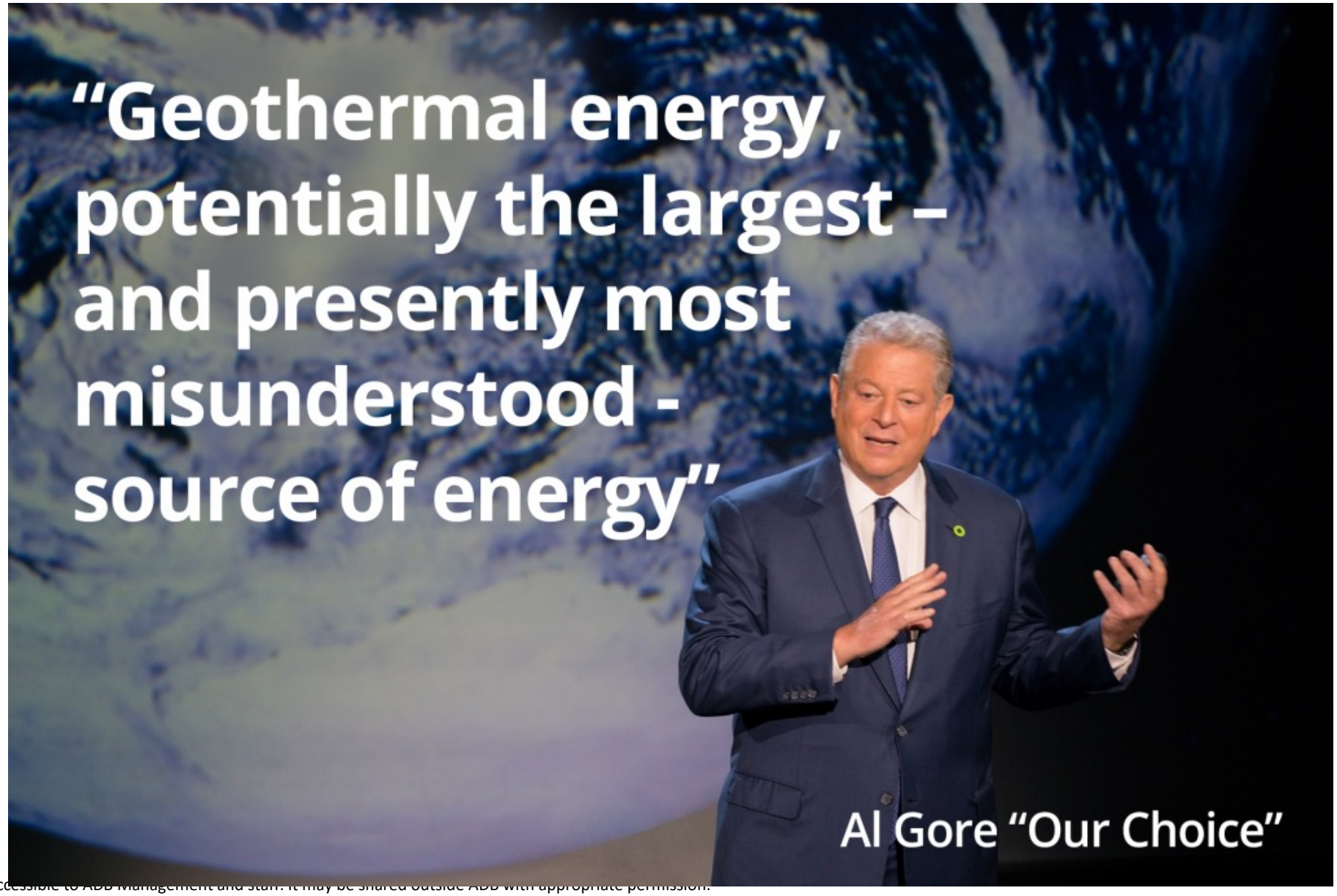
Global geothermal resources are ~ 50,000 times more than total fossil fuel resources



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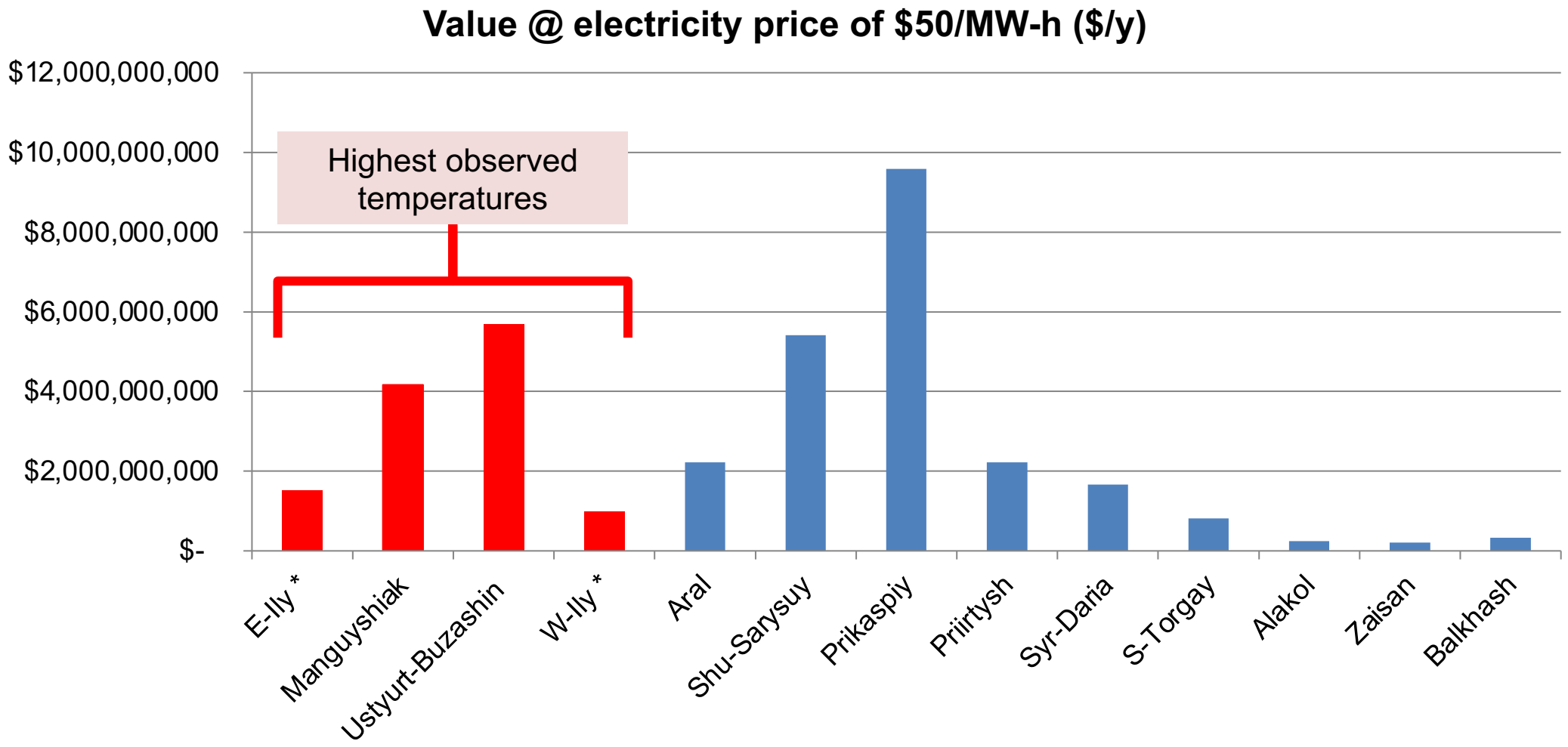
Kazakhstan potential from deep-well / low enthalpy reservoirs > 60,000 KTOE /year



- Basins are ranked by decreasing energy density from left to right. Derived from World Bank. 2019., Table 2.
- Assumes 1% of "raw" resource is extractable, with 10% conversion efficiency using ORC generation systems.
- Ustyurt-Buzashin, Manguyshiak, W-Ily, and E-Ily are most attractive with respect to temperature data.

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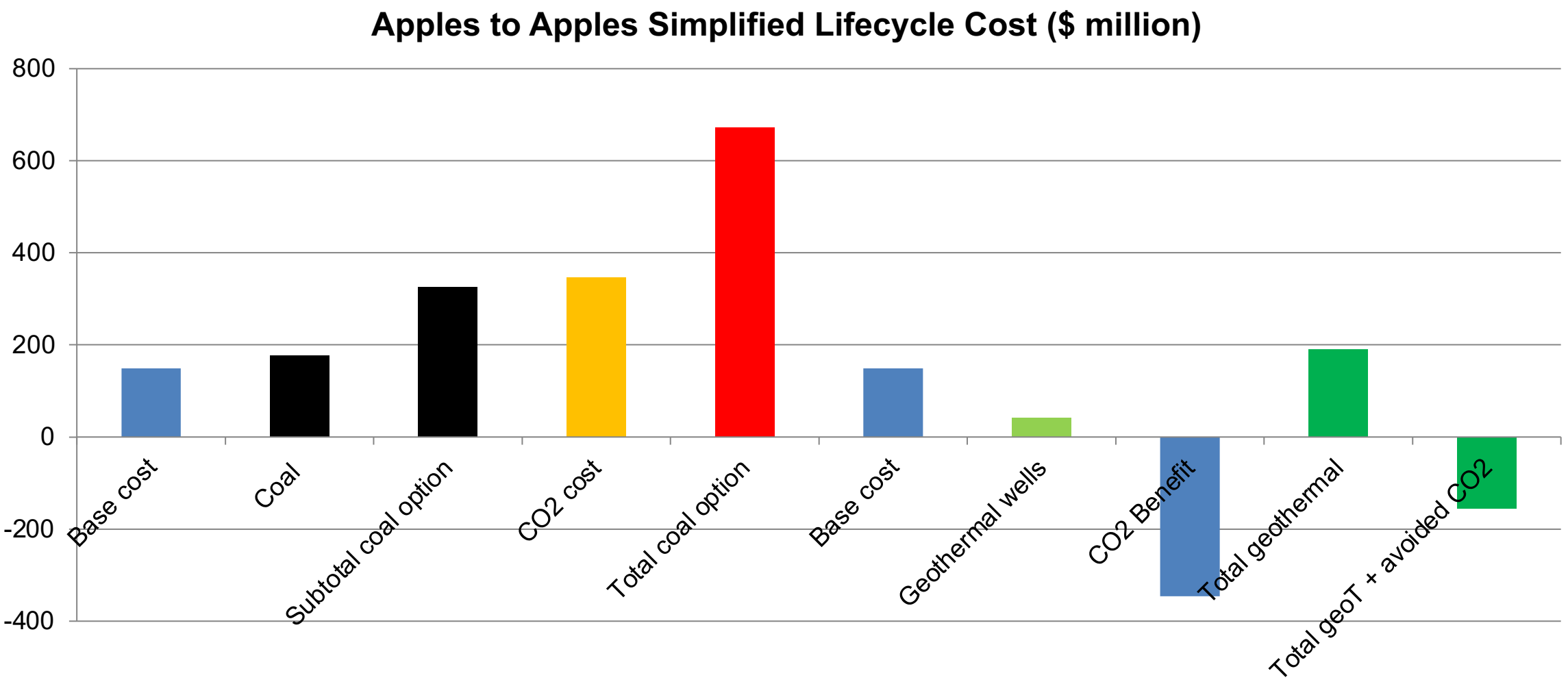
*Geothermal District Heating: 300+ MWth System **

Geothermal option pays for itself when honest accounting is applied!



* Data for Zharkent system from World Bank. 2019. Preliminary Review of Geothermal Resources in Kazakhstan. Final Report Rev. 2. World Bank Group ESMAP. Washington DC. ** Cost of coal assumed at $75/ton, 94,400 tons/year, pre-paid for 25 years of supply.

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Kazakhstan's Energy Wealth – Assumptions for slide #8 (and others)

Greenhouse gas (GHG) Liability = Cost of carbon = $50 / tCO2

Crude oil *

30 billion barrels proven reserves @ $50 / bbl = $1.5 Trillion
1 bbl crude = 1 bbl diesel or gasoline 2.6 kg CO2/Liter gasoline/diesel
2 million bbls/day production in 2020 @ $50 / bbl = $35 Billion / year
GHG liability = $14.7 Billion / year

Natural gas *

5 trillion m3 proven reserves @ $300 / 1000 m3 ($6 / MMBTU) = $1.5 Trillion
CH4 = 0.647 t/1000 m3 x 44/16 = 1.779 CO2 / 100 m3 gas
Sufficient for 30 GW CCGT @ 7000 h/y
30 billion cubic meters/year in 2027 = $9 Billion / year
GHG liability = $2.7 Billion / year

Coal ***

28 billion tons recoverable reserves @$75 / ton = $2.1 Trillion
coal is 80% carbon x 44/12 = 2.93 t CO2 / ton coal
Sufficient for 50 - 60 GW @ 7000 h/y
100 million tons/year production @$75 / ton = $7.5 Billion / year
GHG liability = $14.67 Billion / year

Solar

1% of land area = 27,000 km2
25 MW / km2 = 675,000 MW @ 1400 hours / year (~15% CUF) = 945,000,000 MWh / year
@ $50 / MWh = $47.25 Billion / year

Wind

1% of land area = 27,000 km2
5 MW / km2 = 135,000 MW @ 2920 hours / year (33% CUF) = 394,200,000 MWh / year
@$50 / MWh = $19.71 Billion / year

Solar + Wind with 1% land area => 1323 Terawatt-hour / year vs. 2020 electricity consumption of 108 Terawatt-hour / year

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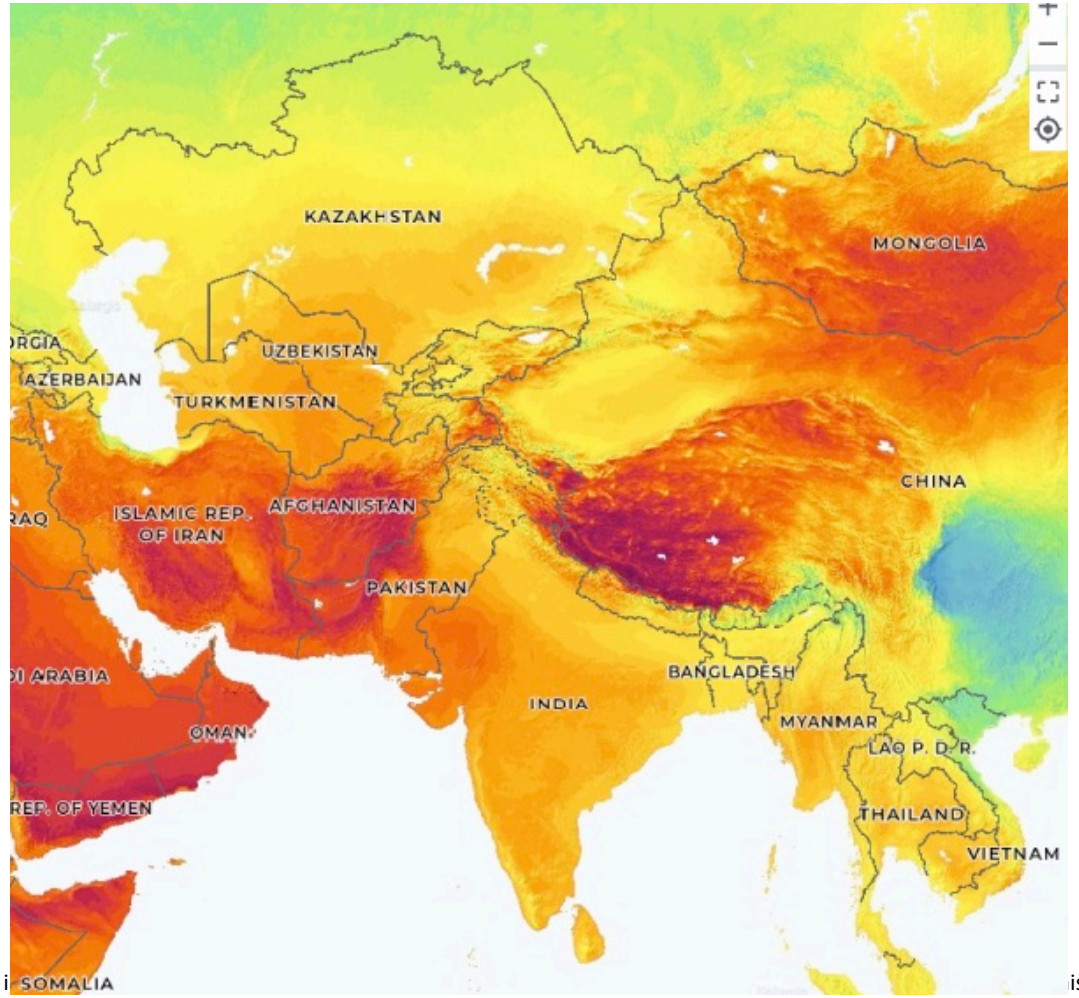
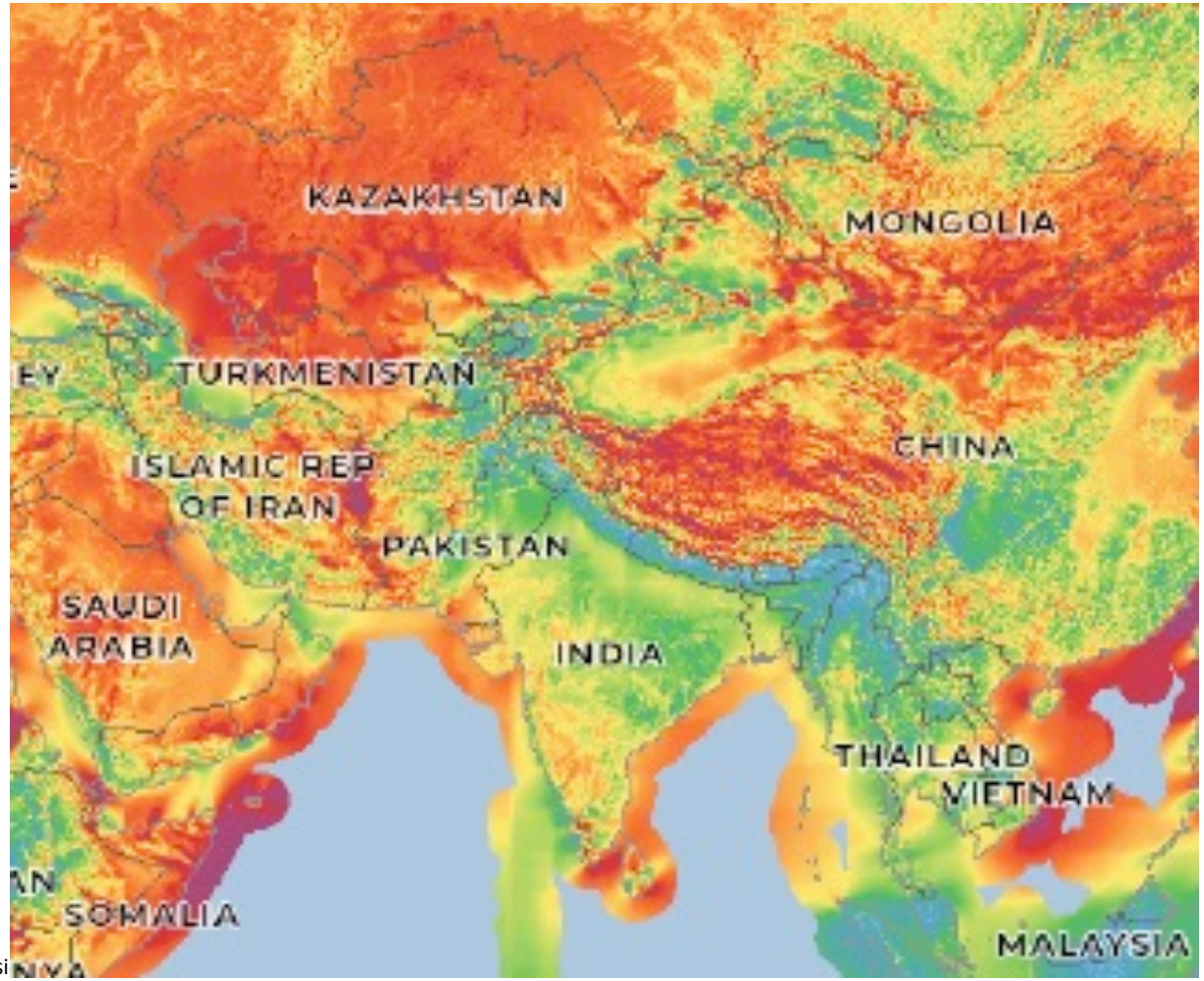
Solar and Wind in Kazakhstan

Kazakhstan Solar Resources:
Not the best but "good enough"
- Comparable to Bangladesh, Cambodia, India, Thailand, southern Viet Nam

Kazakhstan Wind Resources:
Better than "good enough"!
- Better than China, India, Mongolia, Saudi Arabia, and Thailand





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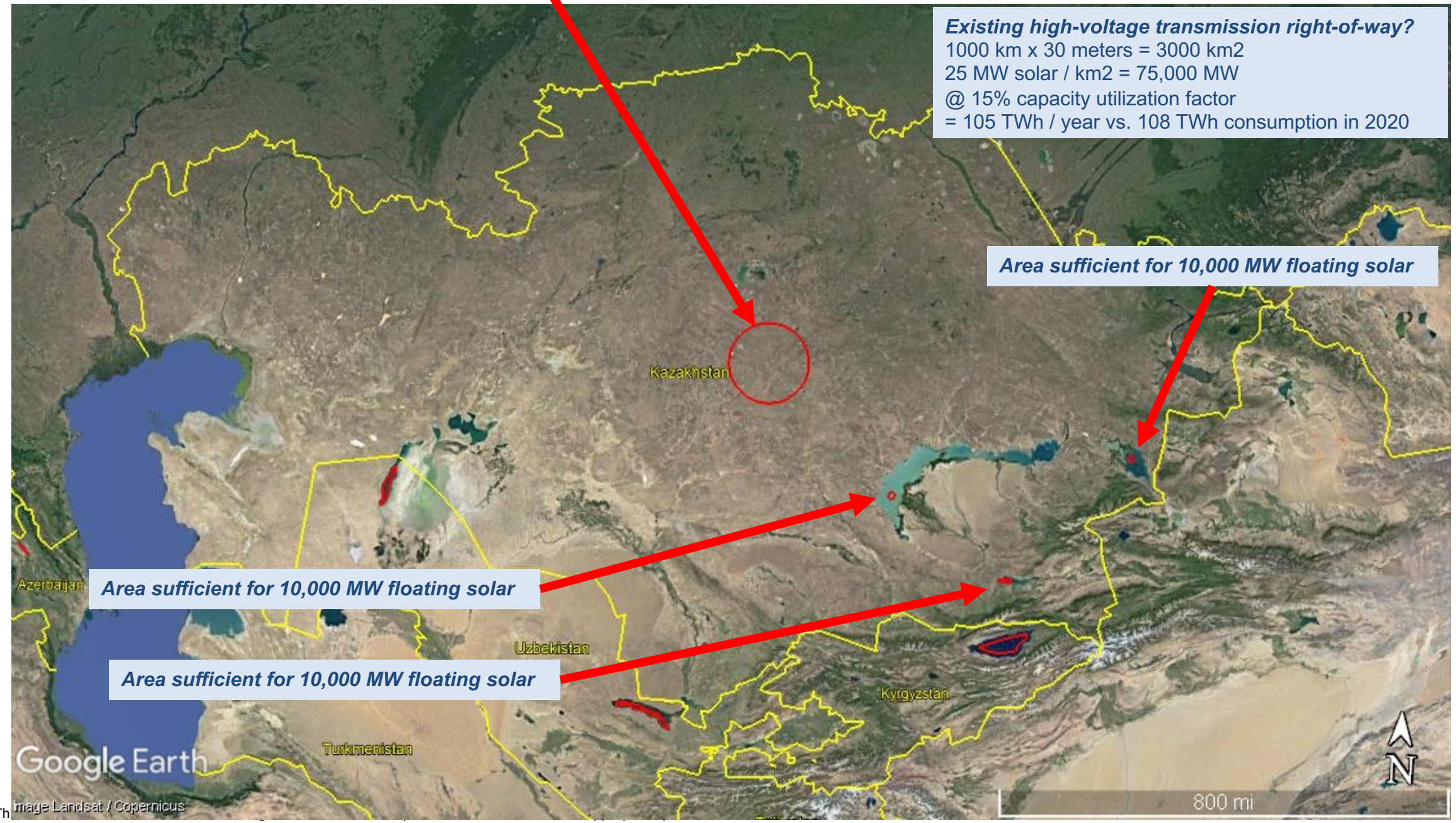
Kazakhstan 1% of land area



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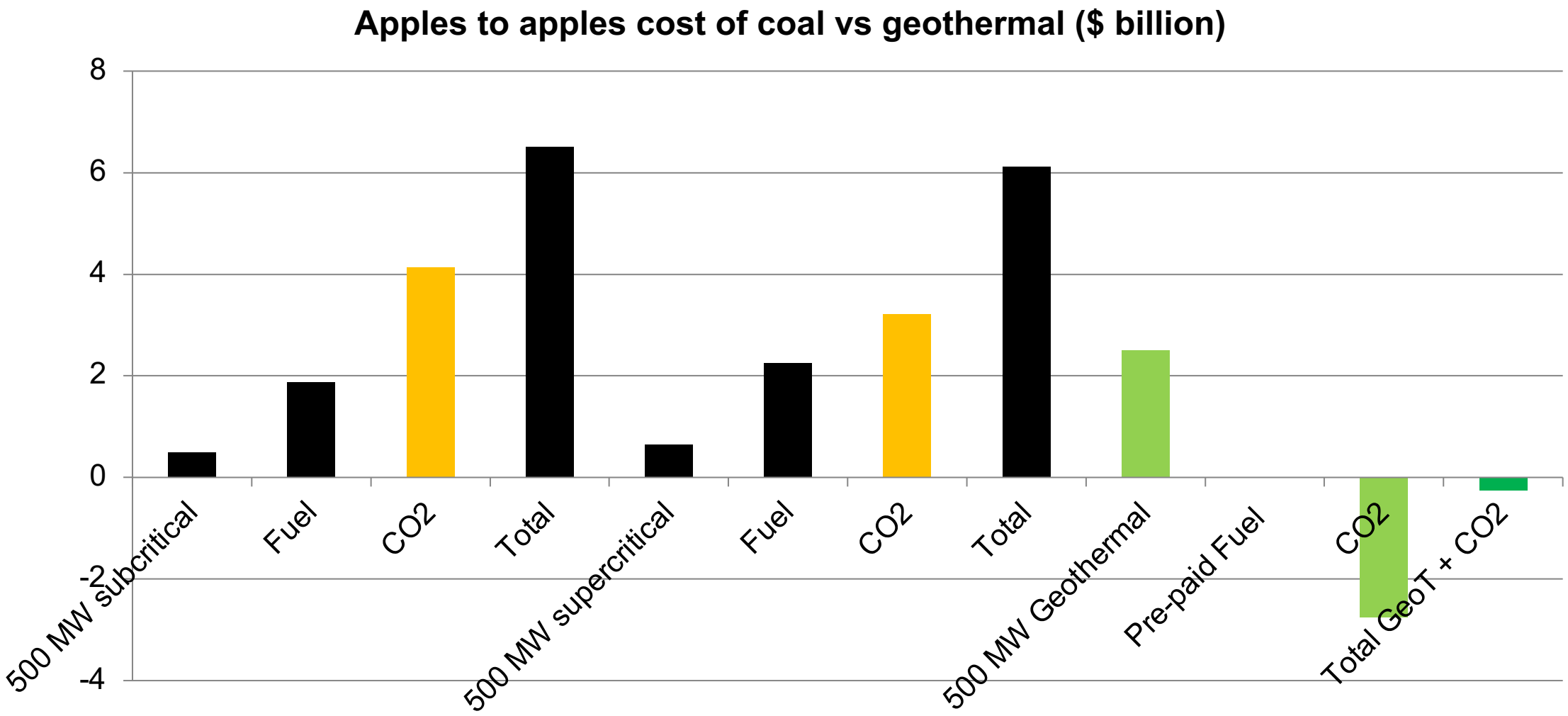
Simplified Life-cycle Cost = Overnight Cost + Pre-paid Fuel + Cost of CO2 => Virtual carbon tax

Geothermal pays for itself on a lifecycle cost basis including cost of carbon!



** Geothermal "fuel" cost = exploration and development drilling costs.

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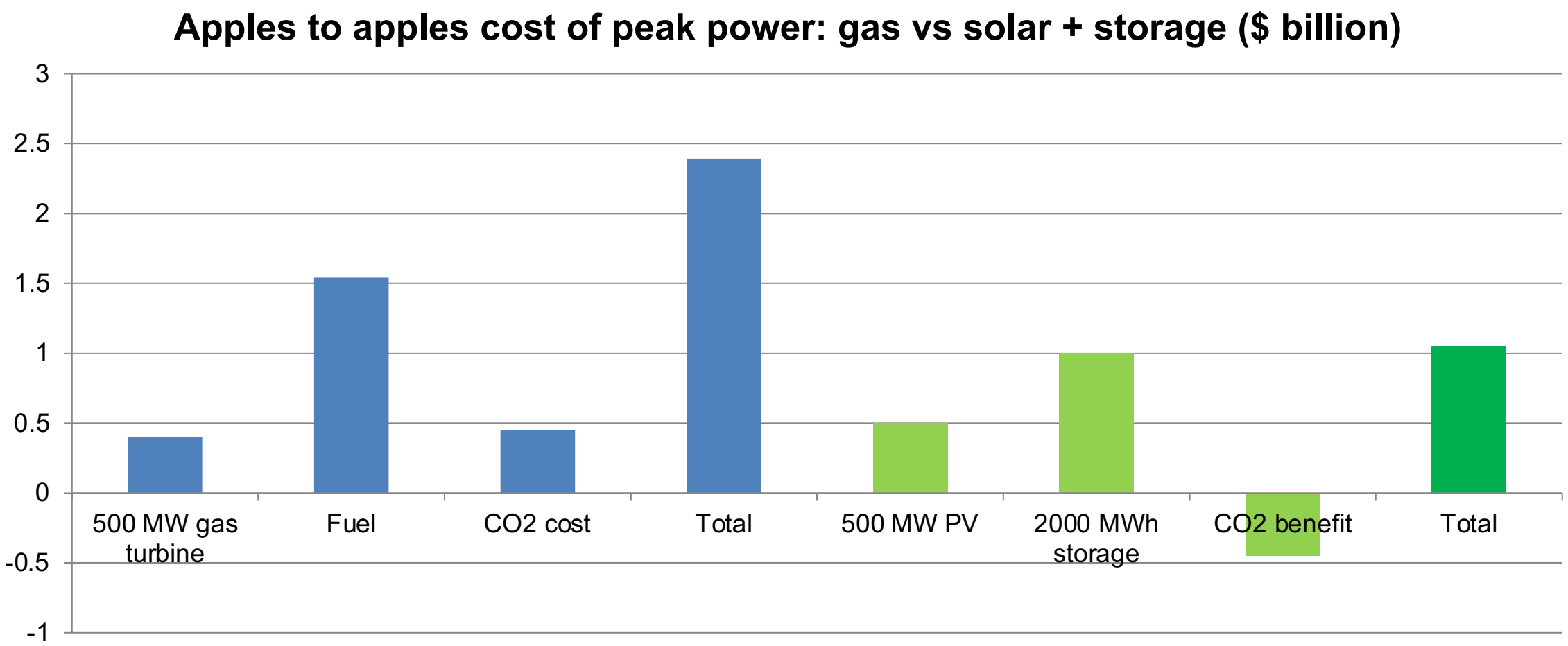
Simplified Life-cycle Cost + Cost of CO2 = Virtual carbon tax



** Solar “fuel” cost is embedded in CAPEX for PV and storage

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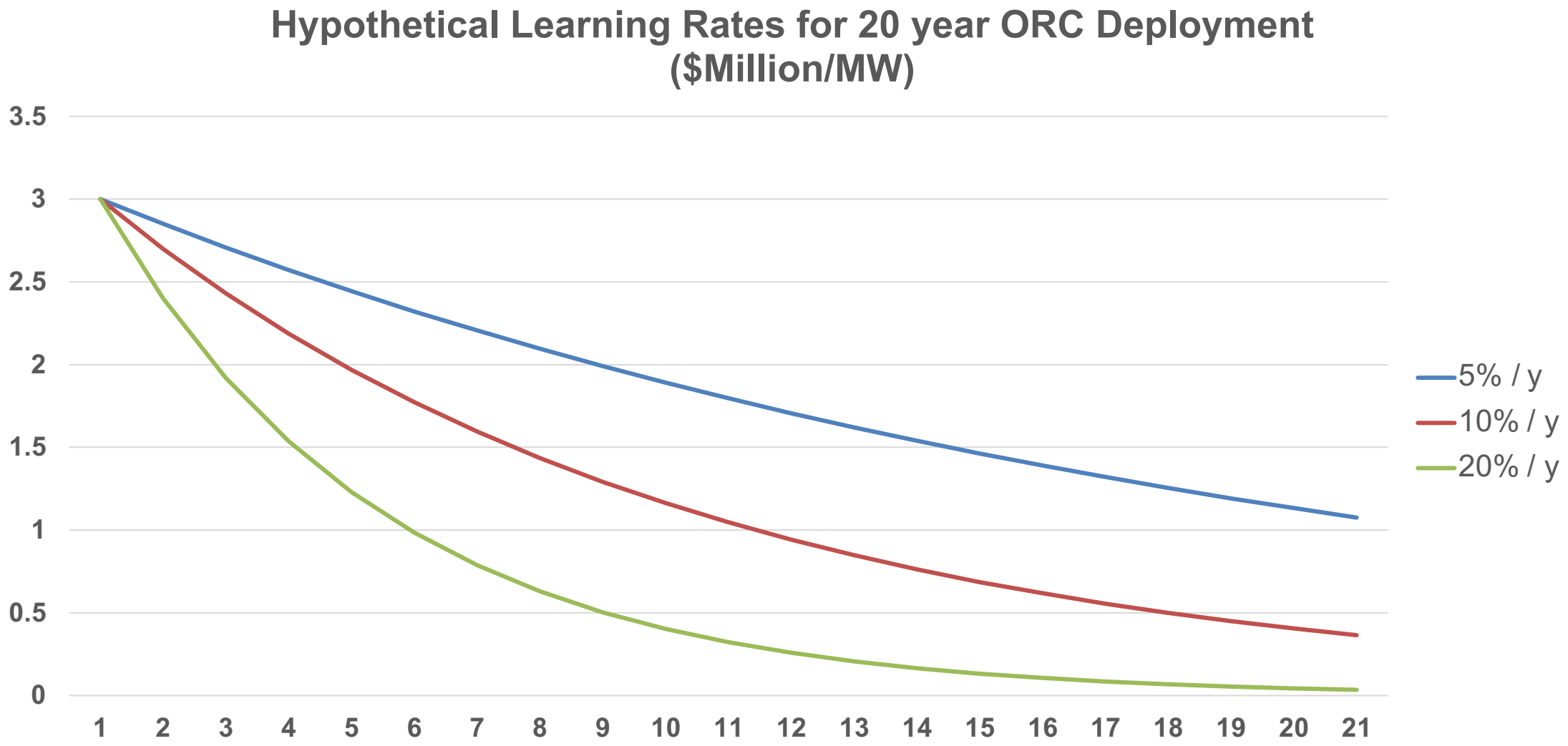
ORC is modular with potential manufacturing economies of scale.
We do not know the "learning rate" but it is possible to create a virtuous cycle of deployment: the more we build, the cheaper it is!



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Possible approach for Reverse BOT to crowd in commercial investment

- **Government develops "shovel ready" project**
- Definition of program and delineation of public vs. private investment activities
- Resource assessment (minimal or no drilling)
- Conceptual design and performance parameters
- Solicitation of early investor pre-payment for right of first refusal on ensuing project(s)

ADB reimbursable grant
(zero interest loan)

- Drilling to confirm resource and reduce development risk
- Acquisition of land and Rights of Way

ADB sovereign investment
(partly monetizing avoided cost of carbon)

- **Tender to Private Sector**

ADB reimbursable grant
(zero interest loan)

- Winner completes drilling program, builds plant, upgrades energy efficiency in buildings, & other heating end-uses
- Winner reimburses government for development costs

ADB non-sovereign investment

- Government collects tax on energy service & other revenues

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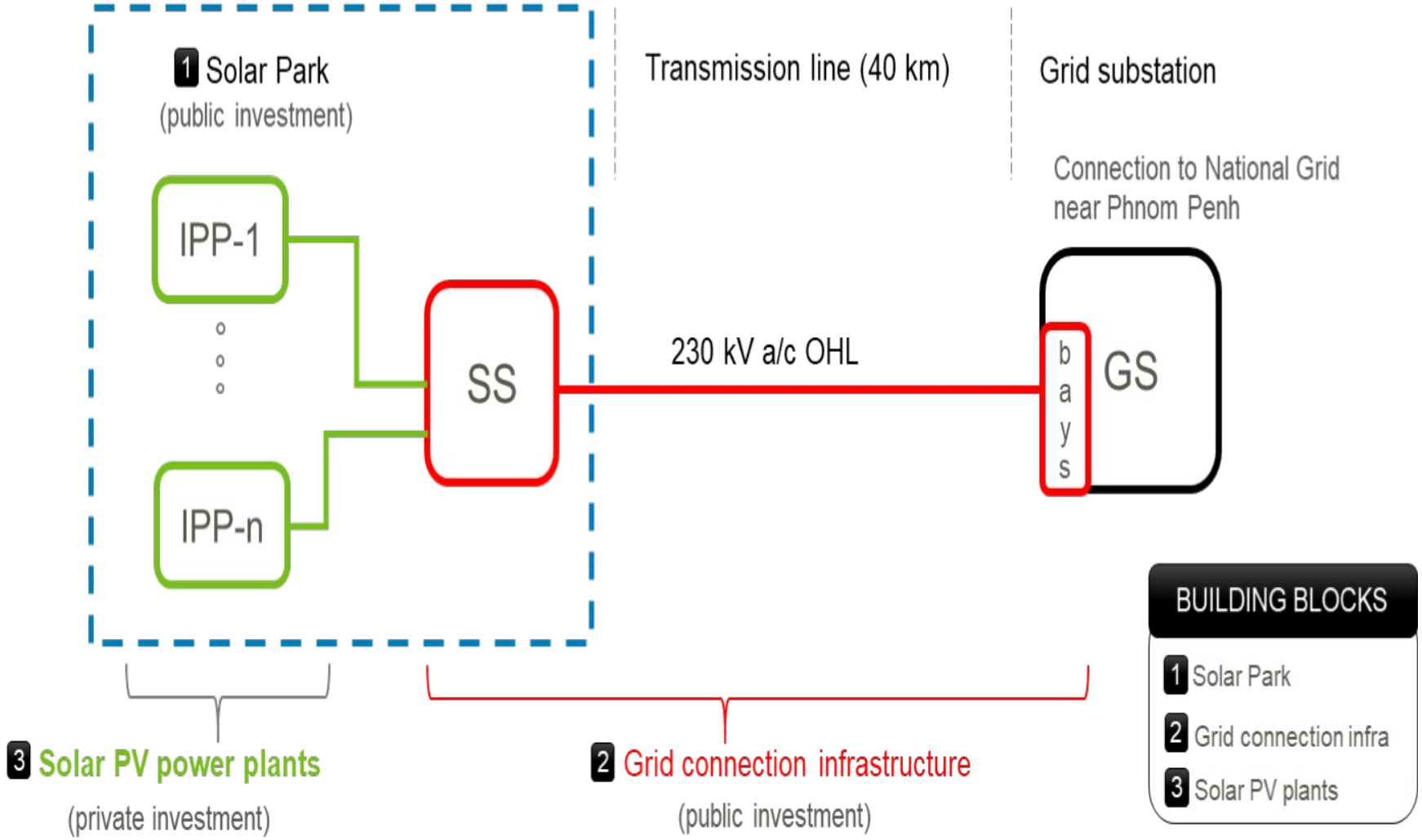
Government develops "shovel ready" project which is tendered to private sector

Cambodia: 100 MW National Solar Park Project



Building Blocks 1 & 2: SERD/OPPP

- Subsector: Electricity Transmission & Distribution
- Approved on 23 May 2019/Signed on 28 June 2019
- $7.6 million project loan (OCR)
- Strategic Climate Fund: $14 million (loan & grant)
- Expected private sector investment: $100 million by 2020

Building Block 3:

ADB-PSOD investment in 60 MW (phase 1)

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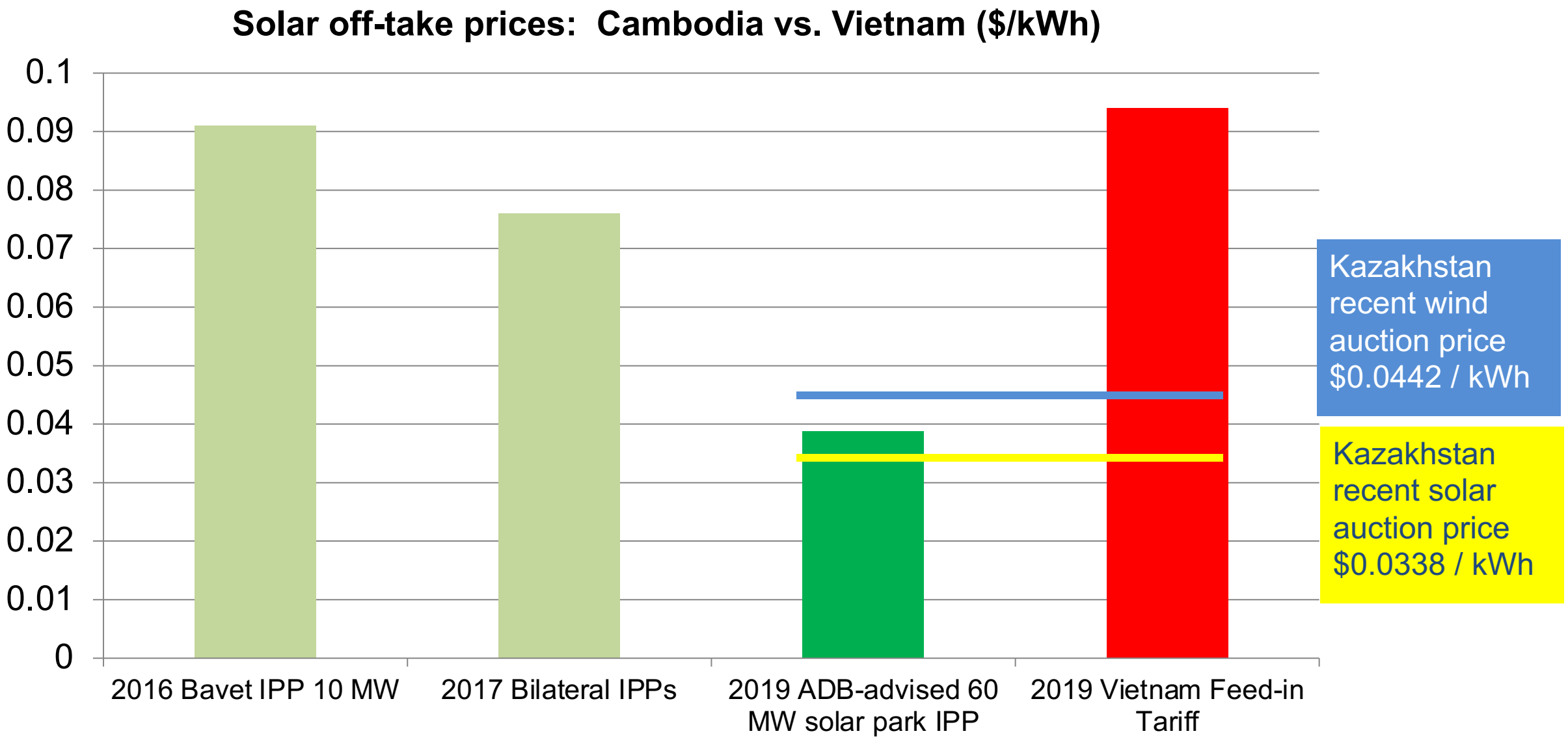
ADB-supported PPP results in lowest solar PPA prices in ASEAN



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